PATENT SPECIFICATION

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(54) HALL MOTOR

(71) We, PIONEER ELECTRONIC CORPORATION, a Japanese Company of No. 15-5, 4-Chome, Ohmori-Nishi, Ohta-Ku, Tokyo, Japan, do hereby declare that the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a Hall motor which utilizes Hall elements in place of the commutators of conventional motors.

Hall motors having a circuit such as is shown in Fig. 1 (see below) have been manufactured and used when it was desired to change the motor speed. Such a motor includes a control circuit C having speed change-over switches S_1 and S_2, and the motor speed can be changed only by the switches S_1 and S_2 of the control circuit.

In more detail, in response to change of the settings of the switches S_1 and S_2 of the control circuit the bias of a transistor T_1 varies, and this serves to control the bias of a transistor T_2 by variation of the collector current of the transistor T_1 so that the collector current of transistor T_2 is increased or decreased. As the collector current of the transistor T_2 increases, this increases the control current flowing through Hall elements H_1 and H_2 in the Hall motor. Thus the Hall voltage generated increases and the current flowing in exciting windings or field windings W_1, W_2, W_3 and W_4 of the Hall motor also increases, so that it is possible to increase the speed of the Hall motor. On the other hand, if the switches S_1 and S_2 of the control circuit are switched so as to decrease the collector current of the transistor T_2, the speed of the Hall motor is decreased.

The motor referred to above has the characteristic curves shown in Fig. 2. This drawing depicts a torque τ of the Hall motor along the abscissa, with respect to which the characteristics of rotation speed n, exciting current I and efficiency η are depicted on the ordinate. Among the curves shown in this drawing, the curve designated as "n_0" is a fundamental rotation speed-torque characteristic curve of the Hall motor, and this seems to correspond to the situation where the control circuit C is not connected. The rotation speed-torque characteristic curves n_1 and n_2 represent the state where the control circuit C is connected and is operating. Now it is assumed that, when the speed change-over switches S_1 and S_2 connect resistors R_1 and R_4 in the circuit, the speed-torque characteristic takes the curve n_1, the exciting current-torque characteristic takes the curve I_1, and the efficiency-torque characteristic takes the curve η_1. In this condition, if the speed change-over switches S_1 and S_2 are switched to connect resistors R_2 or R_3 and R_5 or R_6 in the circuit, the speed characteristic changes so as to vary along the curve n_2, for instance. Nevertheless, the exciting current has exactly the same value in relation to torque as it had before and this characteristic appears on the same exciting current-torque characteristic curve I_1, while, on the other hand, the efficiency varies according to another characteristic curve η_2 differing widely from the efficiency-torque curve η_1. Briefly, therefore, in the prior art Hall motor, changing of the speed caused a variation in efficiency.

It is an object of the present invention to provide a Hall motor in which the efficiency can be maintained substantially constant with change of speed.

In accordance with the present invention there is provided a Hall motor comprising a plurality of energising windings arranged in the current circuits of driving transistors of which the bases are connected with the voltage terminals of Hall elements of the motor, and a control circuit for varying the

control currents of said Hall elements in order to vary the speed of the motor, the said control circuit including a transistor the base bias of which is arranged to be varied by means of an arrangement of changeover switch contacts and resistors, the said energising windings having intermediate tappings arranged to be connected into the current circuits of the driving transistors by means of corresponding changeover switch contacts, the said changeover switch contacts all being coupled for common actuation and the arrangement being such that upon variation of the control currents of said Hall elements to vary the speed of the motor the effective number of turns of each of said energising windings is correspondingly varied to maintain the efficiency of the motor substantially constant.

In accordance with a preferred feature of the present invention the said energising windings of the motor are connected in the current circuits of said driving transistors by way of double pole double throw changeover switches arranged to reverse the direction of flow of current through said windings, the said changeover switches being coupled for common actuation to enable the direction of rotation of the motor to be reversed thereby.

The invention is illustrated by way of example in the accompanying drawings in which:

Fig. 1 is an electrical circuit diagram of a conventional variable speed Hall motor;

Fig. 2 is a graph showing variation of several characteristics of the motor shown in Fig. 1 with respect to torque;

Fig. 3 is a graph showing variation of several characteristics of a motor constructed in accordance with the present invention with respect to torque;

Fig. 4 is a basic circuit diagram illustrating the novel feature of a motor according to the present invention, but from which the speed control circuit of Fig. 1 is omitted for the purpose of explanation.

Fig. 5 is a circuit diagram of an embodiment of a variable speed Hall motor according to the present invention; and

Fig. 6 is a circuit diagram of an embodiment of a variable speed, reversible Hall motor according to the present invention.

Referring to Fig. 4, transistors T_1 and T_2 comprise a speed control circuit, and transistors T_3, T_4, and T_5, T_6 comprise a driving circuit each of which is supplied with its base voltage from a corresponding Hall element H_1 or H_2. Exciting windings or field windings W_1 to W_4 have, respectively, intermediate taps 2, 3 connected to corresponding terminals of switches S_3, S_4, S_5, and S_6, and the movable contacts of the switches S_3, S_4, S_5, and S_6 are connected to the corresponding collectors of the transistors T_3, T_4, T_5, and T_6. Diodes D_1 to D_4 are connected at one end to the corresponding collectors of the transistors T_3, T_4, T_5 and T_6, and their other ends are connected in parallel to a speed control transistor T_1. The base of transistor T_2 is connected to the collector circuit of the transistor T_1 and its base voltage accordingly varies with the collector current of the transistor T_1. The collector current of the transistor T_2 flows into the current terminals of the aforesaid Hall elements H_1 and H_2. The Hall elements H_1 and H_2 sense the magnetic field generated by the rotor of the motor and generate Hall voltages which are supplied as a base voltage alternately to transistors T_3, T_4 and T_5, T_6 so that the transistors T_3, T_4 and T_5, T_6 alternately generate collector voltages to cause a current to flow into the field windings of the motor.

When the movable contacts of the switches S_3, S_4, S_5 and S_6 are connected to their respective terminals 1, a current flows through the full length of the windings and it is assumed that the rotation speed torque characteristic takes the curve n_2' shown in Fig. 3. In this drawing the curve n_0' represents the rotation speed-torque characteristic in the the state where the control circuit is not connected, although the motor would not operate in this condition. The motor which is operating under the curve n_2' has the current-torque characteristic curve I_2. As is well known in the art the efficiency is given by a value which is the output of the motor, or the product of the torque and the speed, divided by the input of the motor, are the product of the energising current and the voltage. The efficiency characteristic in the present case is assumed to be given by the curve η_2.

Now assume that the switches S_3, S_4, S_5 and S_6 of this motor are switched simultaneously (or in interlocked relation) to the respective taps 3. As a result, the number of turns of each of the field windings through which current flows is reduced, so that, if the speed control circuit were absent, the rotation speed-torque characteristic would change to the curve n_0. However, in the embodiment described, the speed control circuit is actually connected, so that this characteristic has the curve n_1.

As is also well known in the art, the torque T is determined by the product of armature current I_a, magnetic flux ϕ, and number of turns N, or is given by the following equation:

$$T = K N \phi I_a$$

where "K" is a constant determined by the configuration of the motor.

In consequence of the foregoing assumption, the number of turns N decreases while "K" and "ϕ" do not change, so that, in

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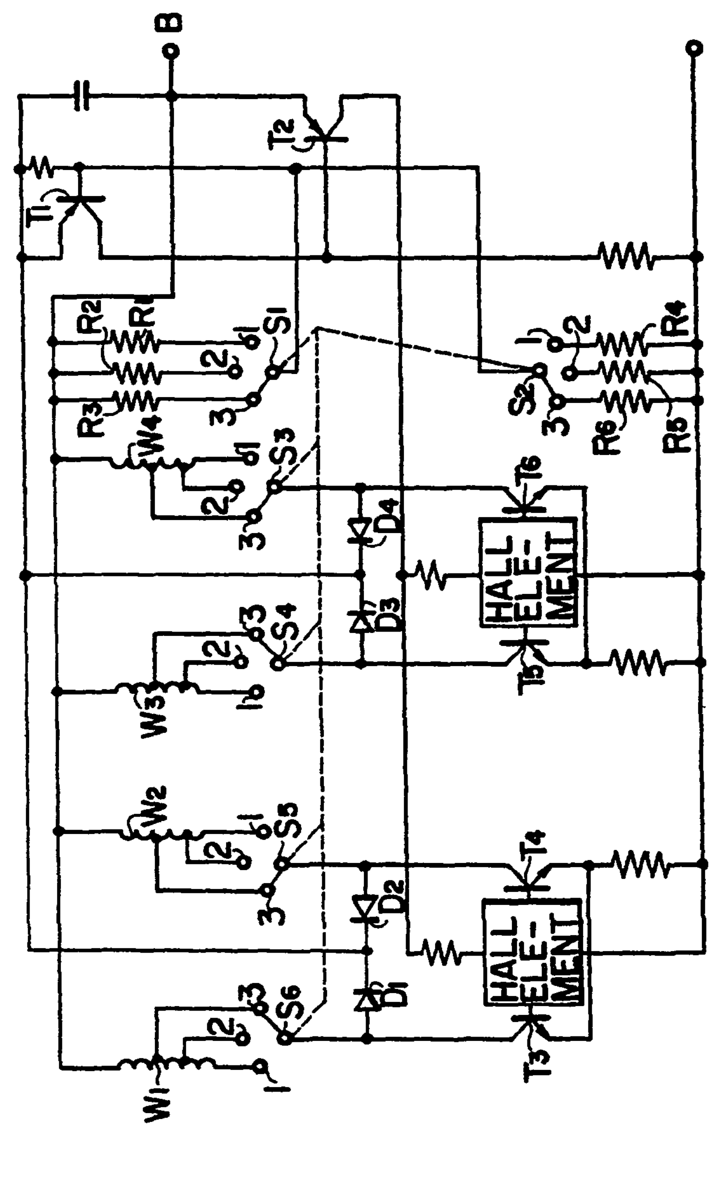
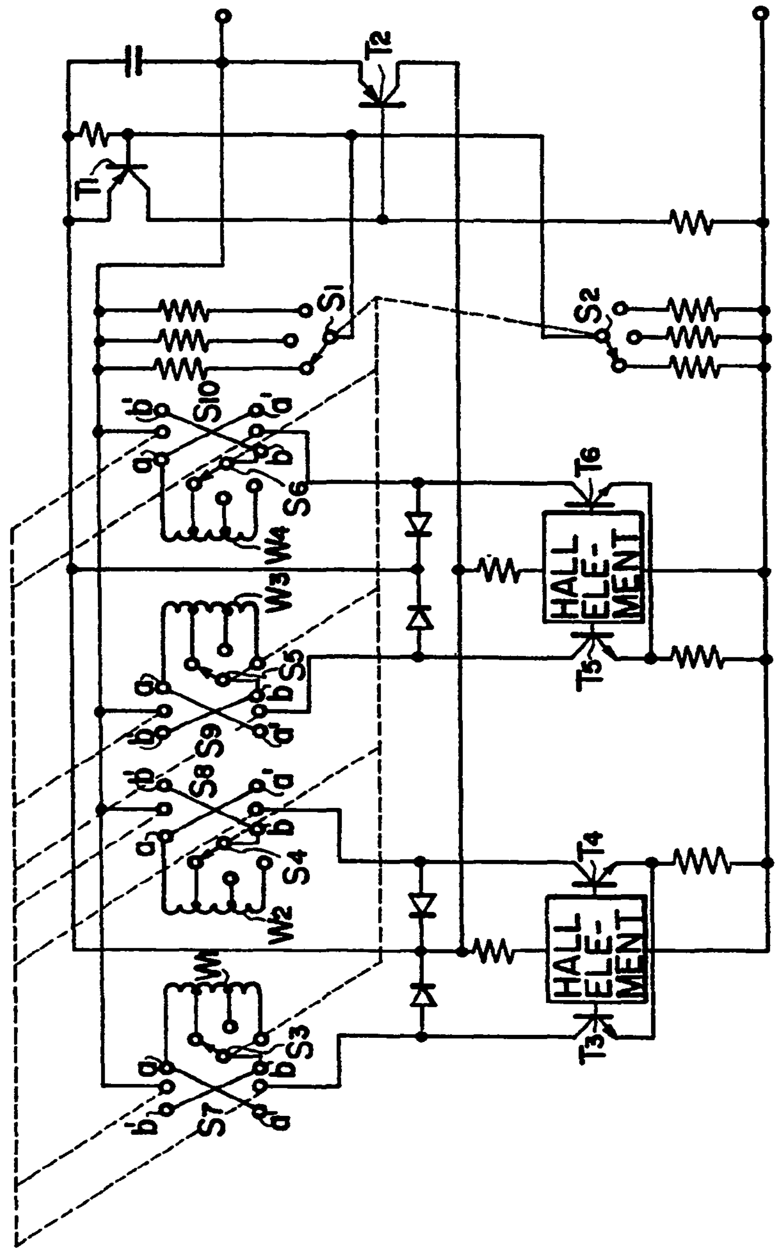
SHEET 3

FIG. 5

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S9
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T3
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T6
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FIG. 6

order to produce the same torque as that produced prior to switching of the switches S_1 through S_6, the exciting current, or I_a, must be increased by an amount corresponding to a decreased number of turns of the winding. Thus, the current-torque characteristic, by means of the switches S_1 to S_6 can be varied along the curve I_1 in Fig. 3. The efficiency in this case is the product of T and n_1 divided by the product of the line voltage and I_1, and is represented by the curve η_1. Accordingly, if the value of n_1 in relation to n_0 is determined by the arrangement of the control circuit so that it is proportional to the value of n_2' in relation to n_0', the values of η_1 and η become substantially identical, and irrespective of the rotation speed it is possible to drive the motor at a high efficiency.

Fig. 5 shows an example of a practical circuit in which the speed change-over feature is incorporated in accordance with the present invention. In this circuit, the bias circuit of the transistor T_1 in the speed control circuit is switched in the same manner as the prior art system, and the number of turns of the field windings of the motor are also changed.

When the switches S_1, S_2, S_3, S_4, S_5 and S_6 used to effect such switching action are actuated in interlocked relation so that the number of turns of the field windings decreases, at the same time, the bias resistors R_1, R_2 and R_3 are also switched to increase or decrease in resistance and the resistors R_4, R_5 and R_6 are switched to decrease or increase in resistance to give appropriate values. In consequence of the foregoing operation, it will be clear that the speed can be increased to reach a given value whilst retaining the efficiency substantially constant.

When the rotation frequency is to be decreased, this can be accomplished by increasing the number of turns of the field windings and this will also be easily understood from the foregoing descriptions.

Fig. 6 shows an example of a circuit enabling both speed change and reverse rotation of the motor, that is, this circuit enables the speed change-over action to be effected during the reverse rotation.

Explaining in more detail, the intermediate taps of the windings W_1, W_2, W_3 and W_4 are connected, respectively, to the switches S_3, S_4, S_5 and S_6 as described above. The movable contacts of the respective switches S_3, S_5, S_4 and S_6 and the other ends of the exciting windings W_1, W_2, W_3 and W_4 are connected, respectively, to corresponding contacts *a* and *b* and *b'* and *a'* of double-pole double-throw changeover switches S_7, S_8, S_9 and S_{10}, one pole of each of the changeover switches being connected to the power source B and the other poles of said switches being connected to the corresponding collectors of the transistors T_3, T_4, T_5 and T_6.

When the movable contacts of the changeover switches S_7, S_8, S_9 and S_{10} are thrown to the *a*, *b* contact side, the beginnings of of the windings W_1 to W_4 connected to the contacts *a* are connected to the power source B and the ends of the windings connected through the switches S_3, S_4, S_5 and S_6 to the respective contacts *b* are connected to the corresponding collectors of the transistors T_3, T_4, T_5 and T_6. On the other hand, when the movable contacts of the switches S_7, S_8, S_9 and S_{10} are thrown to the *a'*, *b'* contact side, the beginnings of the windings W_1 to W_4 are connected to the transistors T_3, T_4, T_5 and T_6 and the ends of the windings W_1 to W_4 are connected to the power source, so that the direction of flow of current through the windings is reversed. Thus the rotating magnetic field generated thereby rotates in the opposite direction with respect to the previous direction, and naturally, the rotor of the motor also rotates in the opposite direction.

As described above, the double-pole double-throw changeover switches S_7, S_8, S_9 and S_{10} are switched in interlocked relation. In addition, the changing of the rotation speed can be accomplished simply by switching the switches S_1 to S_6, with the efficiency unchanged.

As will be seen from the above description the Hall motor according to the invention can accomplish adjustment of the rotation speed without resulting in a variation in its efficiency, and can also provide for reverse rotation; accordingly, it will be clear that the present motor has a high efficiency and is versatile in use owing to the possibility of either forward or reverse rotation with speed change. Thus, the present Hall motor is very suitable for use as a motor for tape recorders which is required to provide forward normal feed, forward fast feed, reverse normal feed, and reverse fast feed functions.

WHAT WE CLAIM IS:—

1. A Hall motor comprising a plurality of energising windings arranged in the current circuits of driving transistors of which the bases are connected with the voltage terminals of Hall elements of the motor, and a control circuit for varying the control currents of said Hall elements in order to vary the speed of the motor, the said control circuit including a transistor the base bias of which is arranged to be varied by means of an arrangement of changeover switch contacts and resistors, the said energising windings having intermediate tappings arranged to be connected into the current circuits of the driving transistors by means of corresponding changeover switch con-

tacts, the said changeover switch contacts all being coupled for common actuation and the arrangement being such that upon variation of the control currents of said Hall el ments to vary the speed of the motor the effective number of turns of each of said energising windings is correspondingly varied to maintain the efficiency of the motor substantially constant.

2. A motor as claimed in Claim 1, in which the said energising windings of the motor are connected in the current circuits of said driving transistors by way of double pole double throw changeover switches arranged to reverse the direction of flow of current through said windings, the said changeover switches being coupled for common actuation to enable the direction of rotation of the motor to be reversed thereby.

3. A Hall motor substantially as described herein with reference to Fig. 5 or Fig. 6 of the accompanying drawings.

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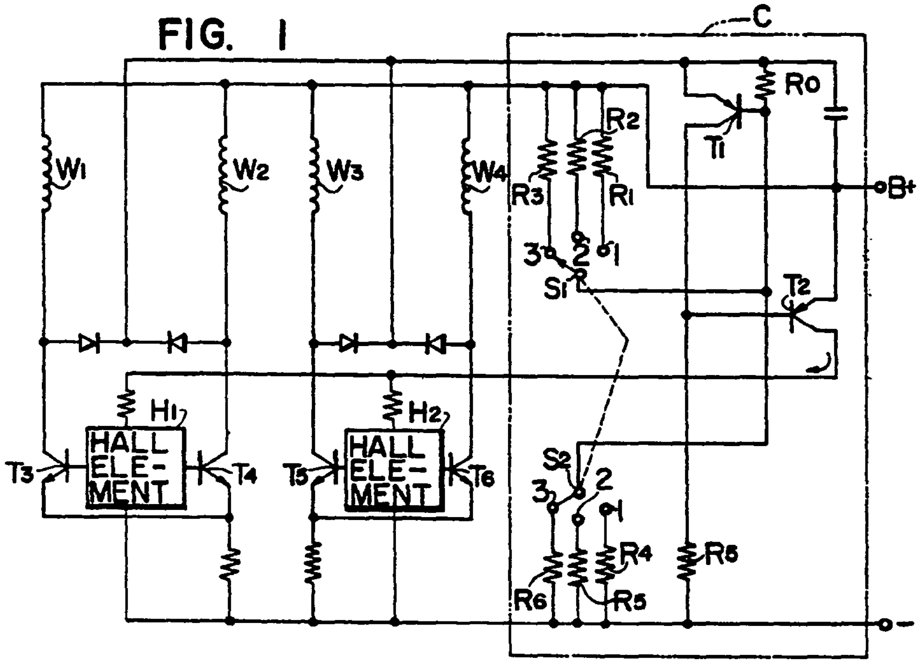
SHEET 1

FIG. 1



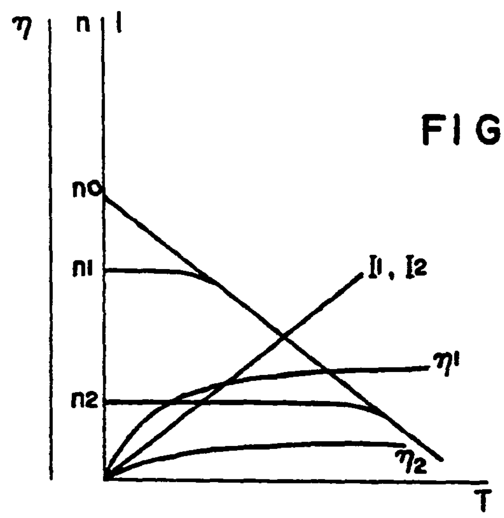
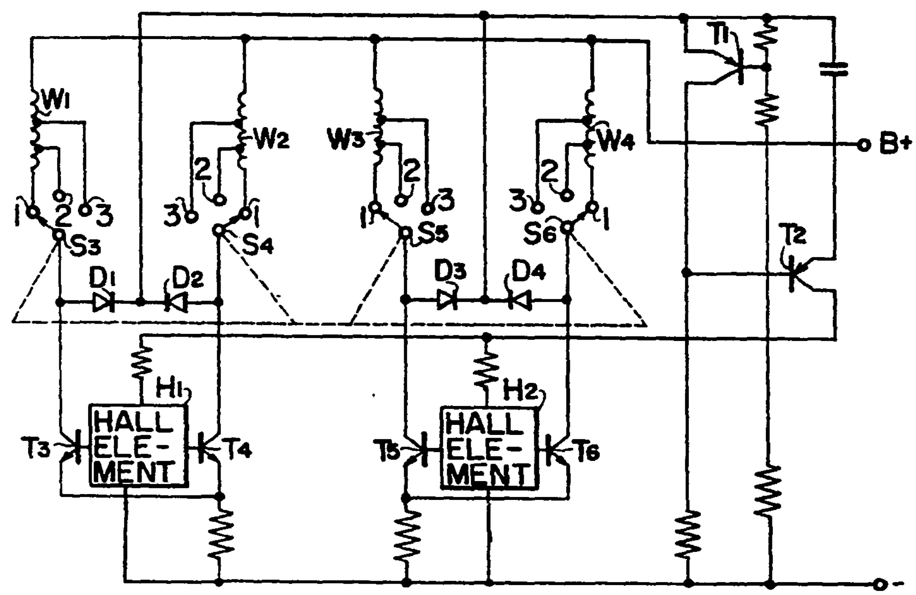


FIG. 2

FIG. 4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HALL ELEMENT
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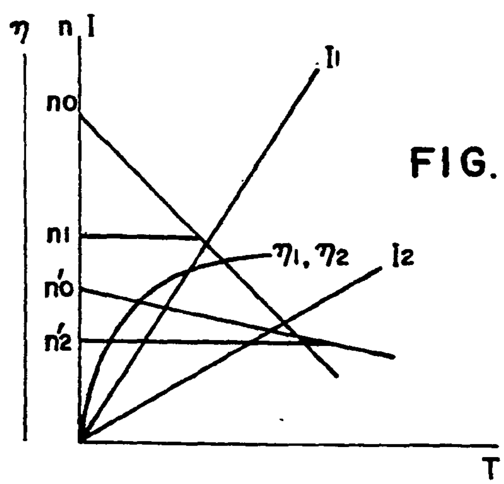
η n I
no
n1
n'o
n'2
I1
I2
η1, η2
T

FIG. 3